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AN EVALUATION OF POTENTIAL REFLECTION PROBLEMS WHEN USING THE NAS MODEL 3d DISPLAY IN THE VERTICAL POSITION IN AIR ROUTE TRAFFIC CONTROL CENTERS

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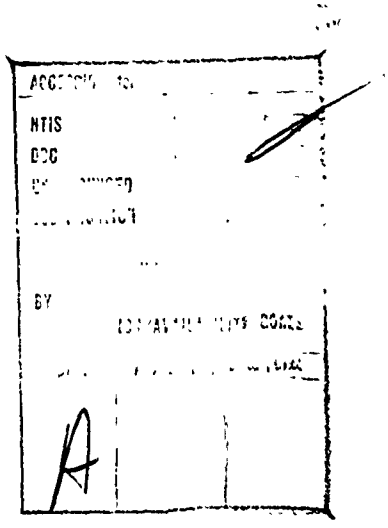

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16. Abstract

A production version of the NAS Model 3d plan view display was taken to the Atlanta, Oakland, and Cleveland Air Route Traffic Control Centers and operated in a sector radar position at each. A typical digital sector display was simulated through the use of a Raytheon 704 computer and tape drive. A total of 166 controllers observed the display and filled out questionnaires on it, 118 seeing the display with the safety shield in place, 48 seeing it with shield removed. Ambient light level measurements were made at each of the centers. A small percentage of the controllers stated that reflections were a serious problem when the safety shield was in place. With the shield removed, a significantly smaller number indicated a reflection problem. There were very large differences in the ambient light levels at the centers.

Details of illustrations in this document may be better studied on microfiche

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INTRODUCTION

Purpose

This study was conducted as part of Project 121-A10-00X, Man/Machine Relationship in NAS En Route Stage A Automation, Subtask Number 1: investigate the possibility of eliminating or significantly reducing the reflection on the plan view display (PVD).

Background

The introduction of NAS Stage A in the Air Route Traffic Control Centers (ARTCC) required the development of a number of new displays of a type never used in centers before. These include the computer readout displays (CRD's) at the A and D positions, the radar controller's computer readout display (RCRD), and PVD operated in the vertical position. The introduction of the CRD's in the A and D positions was accompanied by serious reflection problems emanating from the flight strip bay lighting. While this problem has been solved by using cathode ray tubes (CRT) with bonded implosion shields which have been etched and treated with an antireflective coating, it called attention to the question of whether there might not be a reflection problem in operating the PVD's in a vertical position.

Potential reflections on the PVD in the centers could not be evaluated at the National Aviation Facilities Experimental Center (NAFEC) System Support Facility (SSF) because of the great differences in both ceiling height and manner of lighting between the SSF and the centers. It was decided that only by looking at the PVD in one or more centers could a reasonable determination be made of presence of reflections and their potential impact on the controllers. This report summarizes the results of the evaluation that was conducted.

DISCUSSION

Procedure

A production version of a Raytheon Model 3d PVD (Serial No. 22) was taken to three ARTCC's (Atlanta, Oakland, and Cleveland) and installed and operated in a sector radar position in each. A special shipping case was designed and built at NAFEC to allow the PVD to be shipped to the centers without damage (see Figures 1 and 2). A typical digital sector display was simulated through the use of a Raytheon 704 computer and tape drive. The information displayed was developed by Raytheon for the Paris Air Show and the Tokyo Trade Fair, and while rather commercial in flavor, it does provide a technically accurate presentation of traffic in a Boston sector, complete with tracked targets, visual flight rules (VFR) traffic, handoffs, and a weather display. A sound track accompanies the display and, in addition to extolling the virtues of the display, gives a description of some of its more important features. The presentation takes about 6 minutes to run through.

The general procedure for obtaining controller opinions on the display was to seat them, either singly or in pairs, before the display and have them read a brief explanation of the purpose of the evaluation (see Figure 3). They next observed the prerecorded demonstration of the display, and finally filled out the questionnaire (see Figure 4). Questions raised by the controllers about various features of the display were answered whenever possible.

At each of the three centers, questionnaires were filled out after observing the display, both with and without the flat safety shield in place. This was done to evaluate the potential reduction in reflections that might be obtained by removing the safety shield, which is no longer needed as the new all-glass tubes have an implosion shield bonded to the CRT.

In addition, ambient light measurements were made at each of the centers to estimate the variability in lighting from center to center and to determine, if possible, whether there is any relationship between the lighting level and the reflection problem.

Results

Safety Shield in Place. The first four questions of the questionnaire related to the presence of a visibility problem with the display, its cause, and its severity. The answers to the first question, "Did you have any difficulty seeing any part of the display?," may be summarized as follows:

	Yes	No
Atlanta	4 (11.8%)	30 (88.2%)
Oakland	17 (38.6%)	27 (61.4%)
Cleveland	12 (30.0%)	28 (70.0%)
Combined	33 (28.0%)	85 (72.0%)

A Chi Square Test of the above data shows that the difference in response among the centers is statistically significant at the 5 percent level of confidence.

The second question asked the controller to indicate on a diagram the location of the visibility problem, if he had answered yes to Question 1. All of the respondents indicating a location showed it to correspond to reflections of ceiling lights or lights from map boards across the aisle. This was confirmed by examining photographs of the displays.

Question 3 asked the respondent to identify the cause of the problem, if a problem was indicated in Question 1. In all cases in which a cause was identified, it was stated to be "reflections or glare."

Question 4 asked the respondent to specify the severity of the problem, if a problem had been indicated. Responses are summarized as follows:

	Could not see what was displayed	Could barely see what was displayed	Could see with some effort	Other
Atlanta	0	0	4	0
Oakland	2	0	14	0
Cleveland	0	0	10	0
Combined	2	0	28	0

Of the 30 controllers who responded to this question, 28 responded with the alternative indicating the minimum degree of severity, while two chose the alternative indicating the most severity.

Summarizing the results of the first four questions, 72 percent of the controllers found no visibility problems. Of the 28 percent who found a problem, all those who specified a cause stated it was due to reflections and glare. Of the latter group, 93.3 percent indicated the problem was comparatively minor, 6.7 percent said it was so serious that information displayed in the reflection areas "could not be seen." The latter comprised 1.7 percent of this sample.

The final question asked was, "Under these conditions, what is your overall evaluation of the quality of the display for air traffic control?" The responses were as follows:

	Excellent	Very Good	Fair	Acceptable	Not Acceptable
Atlanta	14 (42.4%)	16 (48.5%)	1 (3.0%)	1 (3.0%)	1 (3.0%)
Oakland	14 (32.6%)	17 (39.5%)	4 (9.3%)	4 (9.3%)	4 (9.3%)
Cleveland	10 (25.6%)	24 (61.5%)	1 (2.6%)	3 (7.7%)	1 (2.6%)
Combined	38 (33.0%)	57 (49.6%)	6 (5.2%)	8 (7.0%)	6 (5.2%)

A Chi Square Test of the above data showed no statistically significant differences between centers at the 5 percent level of confidence. Looking at the data in another way, one can see that 33 percent of the sample of 115 controllers thought the display was excellent, 82.6 percent thought it very good, or better, 87.8 percent thought it was at least fair, 95.8 percent thought it was at least acceptable, while 5.2 percent did not think it was acceptable for air traffic control.

Before discussing these results further, the data obtained from the controllers, with the safety shield removed, will be presented. Removal of the safety shield is being considered for two reasons: First, because

an implosion shield has already been bonded directly to the tube, it is no longer needed as a safety device; secondly, the removal of the flat glass surface should reduce the number and intensity of reflections on the display.

Safety Shield Removed.

Question 1, "Did you have any difficulty seeing any part of the display?"

	Yes	No
Atlanta	0 (0)	10 (100%)
Oakland	3 (15.8%)	16 (84.2%)
Cleveland	3 (15.8%)	16 (84.2%)
Combined	6 (12.5%)	42 (87.5%)

Because of the small sample, a statistical test was not made for differences between centers.

Questions 2 and 3 on the location of the visibility problem on the display and the cause of the problem showed that the six controllers who reported difficulty attributed it to glare and reflection.

The six controllers who responded to Question 4, reported they could see all parts of the display, but "with some effort."

Question 5, "Under these conditions, what is your overall evaluation of the quality of the display for air traffic control?", was answered by 47 of the 48 controllers as follows:

	Excellent	Very Good	Fair	Acceptable	Not Acceptable
Atlanta	5 (55.6%)	4 (44.4%)	0 (0)	0 (0)	0 (0)
Oakland	12 (63.2%)	5 (26.3%)	0 (0)	2 (10.5%)	0 (0)
Cleveland	7 (36.8%)	10 (52.6%)	0 (0)	1 (5.3%)	1 (5.3%)
Combined	24 (51.1%)	19 (40.4%)	0 (0)	3 (6.4%)	1 (2.1%)

The limited Atlanta sample precluded a statistical test for differences between centers. Summarizing the data in the same way as was done for questionnaires completed with the shield in place, we find that 51.1 percent of the 47 responding controllers who observed the display without the shield found it excellent; 91.5 percent rated it very good or better; 97.9 percent thought it at least acceptable; and 2.1 percent found it unacceptable.

Survey of Center Lighting Intensity. Ambient light level measurements were made in each center with a standard Weston footcandle meter. While some measurements were made at individual consoles or positions, they varied considerably within a center due to intensity setting preferred by individual controllers and are not particularly germane to the general reflection problem. Figure 5 shows light levels measured in the three centers for similar locations in the center. Representative footcandle measures for the three centers are as follows:

	High	Low	Median
Atlanta	21	8.5	15
Oakland	9	3	7
Cleveland	2.75	1.5	2.0

The reason for the centers choosing to operate at such widely varying lighting levels is not known at this time nor do we know whether other centers fall within this range or outside it at either end.

Summary

There is a tendency, when data are obtained, to regard them as somehow final or conclusive. The interpretation of the preceding data is highly contingent on many factors involved in their collection: The controllers were asked to evaluate the quality of the display without having the opportunity to actually control traffic with it; they were asked to make a judgment after seeing the display for less than 10 minutes; many of the controllers had been exposed to comments about the display by earlier subjects; the material presented on the display was quite novel to most of them; and, finally, there were often curious controllers standing behind them while they were looking at the display. These and other uncontrollable factors undoubtedly influenced some opinions. Interpretation of the data must, therefore, be made with caution.

Before proceeding to any general analysis, some of the inter-center differences should be considered. As was already mentioned, the only statistically significant difference between centers was in response to the question, "Did you have any difficulty seeing any part of the display?" The percent of "yes" responses was: Atlanta - 11.8 percent, Oakland - 38.6 percent, Cleveland - 30.0 percent. The difference between Atlanta and Oakland was statistically significant at the 1 percent level of confidence, while the difference between Atlanta and Cleveland was not quite significant at 5 percent level. While this was the only question in which statistically significant differences were found, the same trend runs through most of the other questions, i.e., Atlanta controllers more favorable, less critical than either Oakland or Cleveland. If numerical values are assigned to the overall rating as follows: excellent - 4, very good - 3, fair - 2, acceptable - 1, not acceptable - 0, an average rating can be computed for each center. With the safety shield in place these ratings were Atlanta - 3.2, Oakland - 2.8, Cleveland -

3.0. With the shield removed, Atlanta 3.6, Oakland 3.4, Cleveland 3.1. While these differences are not statistically significant, they are consistent with the data from Question 1 and there does seem to be a definite trend.

With respect to the center lighting, the differences were quite large, not only in brightness, but in the quality of the lighting. Atlanta and Oakland have conventional, louvered fluorescent lighting in the ceiling. Cleveland has, in addition to the conventional lights which are not normally used, upward facing fluorescents mounted on the top of the plenums (see Figure 6). These are capable of throwing a very even light on the ceiling without any hot spots and the difference is readily apparent in the type of reflections that are seen by the controllers (see Figures 7, 8, and 9).

It would have been reasonable to expect that the Cleveland lighting, with its very low ambient level, its evenness, and its lack of reflected light fixtures would be most compatible with a vertical plan view display (PVD). The differences between Cleveland and Oakland, and especially between Cleveland and Atlanta, with respect to these characteristics should have been reflected in the controller ratings--assuming the initial hypothesis is correct, and assuming that other countervailing effects are not operative. There are several possible explanations of the apparent contradiction between the viewing conditions and the controllers' responses.

One possibility is that there are organizational or geographic variations between centers which are reflected in general attitudinal differences with respect to the agency, to automation, to National Airspace System (NAS), or to new equipment. It may be that there are center morale differences which are reflected in judgments on specific equipment where there is room for subjectivity. If this is so, then the ratings may reflect not so much a difference in lighting as a difference in controllers. This could be tested experimentally by interchanging the Cleveland and Atlanta lighting, and having the display reevaluated--except that the ratings would then reflect the possible disruption of a major environmental change. For the present, any thinking along this line will have to remain in the area of speculation.

The other possibility is that there are differences in the viewing conditions in the three centers that materially affect the amount and subjective effect of the reflections. Observation of the display in the centers and study of the photographs showed that there are, in fact, two types of reflections operating. In Atlanta and Oakland the primary source of reflections had to do with light sources, i.e., reflections of ceiling lights in the center ceiling or the observation corridor, or reflections from back-lighted map boards. These can be seen in Figures 7 and 8. These reflections are characterized by being fairly small in area and having sharp contours and high brightness levels. The other kind of reflection was only noticeable in Cleveland with the plenum or indirect lights on (see Figure 9). It is a low-level reflection of the entire ceiling area, except as obscured by the consoles. This reflection is characterized by being large in area and of relatively low brightness.

The two types of reflections create entirely different problems for the controllers. The reflections of ceiling lights tend to approach the brightness of the display information and so reduce its apparent contrast. The reflections were never sufficient, however, to cause any serious difficulty in reading any part of the display, even though no controller set the display brightness above 15 footlamberts while the display is capable of producing 50 footlamberts. There was even less of a visibility problem at Cleveland where reflections were far less bright and so affected contrast even less than the Atlanta and Oakland ceiling lights. A different phenomenon was at work at Cleveland, the creation of silhouettes of anyone standing or walking behind the controller (see Figure 9). Several controllers commented that this was quite distracting, even though it was obvious it did not interfere with their ability to see the displayed material. This should be kept in mind in evaluating the questionnaire responses.

The response of the controllers in the three centers to the display with the safety shield in place was, by and large, favorable. While 28 percent answered the question, "Did you have any difficulty seeing any part of the display?" in the affirmative, only 5.2 percent felt it was unacceptable under the conditions they observed it. This should be compared to the 33 percent who found it excellent and the 49.6 percent who found it very good. Still, we cannot recommend the installation of equipment that would be unusable from either a safety or human factors standpoint for even 5 percent of the controllers who must use it. In evaluating these data, it seems relevant that 4 of the 6 unacceptable ratings came from Oakland where reflected ceiling light fixtures were most conspicuous. It must be kept in mind that the controllers' judgments reflected not only what they saw during their 10 minutes at the console, but also their opinions on the probable effect of using the display for several hours. Some of them undoubtedly felt that the reflections would become more and more annoying and troublesome as time went on and expressed this idea in their unacceptable ratings. While this is a perfectly reasonable position, a contrary viewpoint is also tenable, i.e., the reflections were quite noticeable because the observers had little to do but look at them and they would virtually "disappear" as the controller became immersed in the air traffic control task. The phenomenon is called "adaptation" and it can be demonstrated in a wide variety of environmental problems such as noise, odors, flicker, etc.

Since each CRT now comes with an implosion shield bonded to it, the flat glass safety shield in front of the tube is no longer necessary from a safety standpoint. Our experience with the CRD's indicated that such a shield contributed materially to the reflection problem, and it was decided that some observations should be made with it removed. Figure 10 shows the PVD at Cleveland with the safety shield removed. A comparison of responses to Question 1, "Did you have any difficulty seeing any part of the display?" showed that when the three centers are combined 28 percent of the controllers answered yes with the shield in place as opposed to 12.5 percent with the shield removed. This is a statistically significant difference at the 5 percent level of confidence. Responses to the other questions did not show

statistically significant differences between the shield/no shield conditions, but all the differences obtained were in favor of removing the shield. Even the "Not Acceptable" ratings went from 5.2 percent to 2.1 percent with the shield removed, with only one controller out of 47 giving that rating.

The Model 3d display has tremendous brightness reserves which will probably never be used by the controllers. Almost everyone responded favorably to the cleanness of the display and the clarity of the alphanumerics, maps, and symbology.

CONCLUSIONS

Based on the above analysis it is concluded that:

1. The Model 3d display, operated in the vertical position with the safety shield in place, will be acceptable to most controllers for operational use. A small percentage of controllers will have problems with the reflections, but this may clear up as they become used to working with the display. Adjustment of the center lighting level and installation of additional louvers or baffles can further reduce whatever problems remain.

2. Removal of the safety shield considerably reduces the size and brightness of the reflections. Use of the display with the safety shield removed will present no problem to most of the controllers from a reflection standpoint.

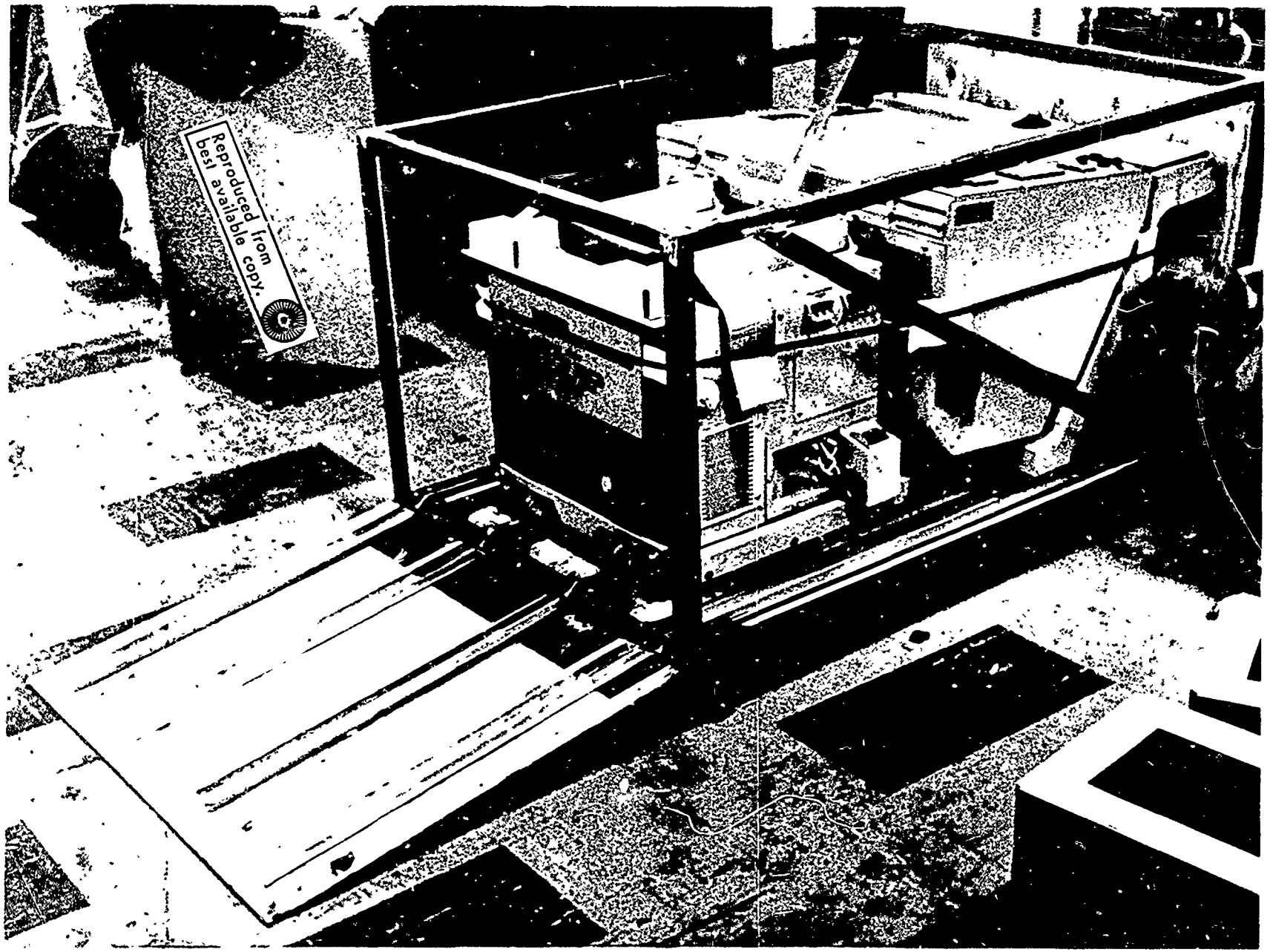

FIGURE 1 - SHIPPING CASE SHOWING END PIECE IN POSITION FOR LOADING AND UNLOADING

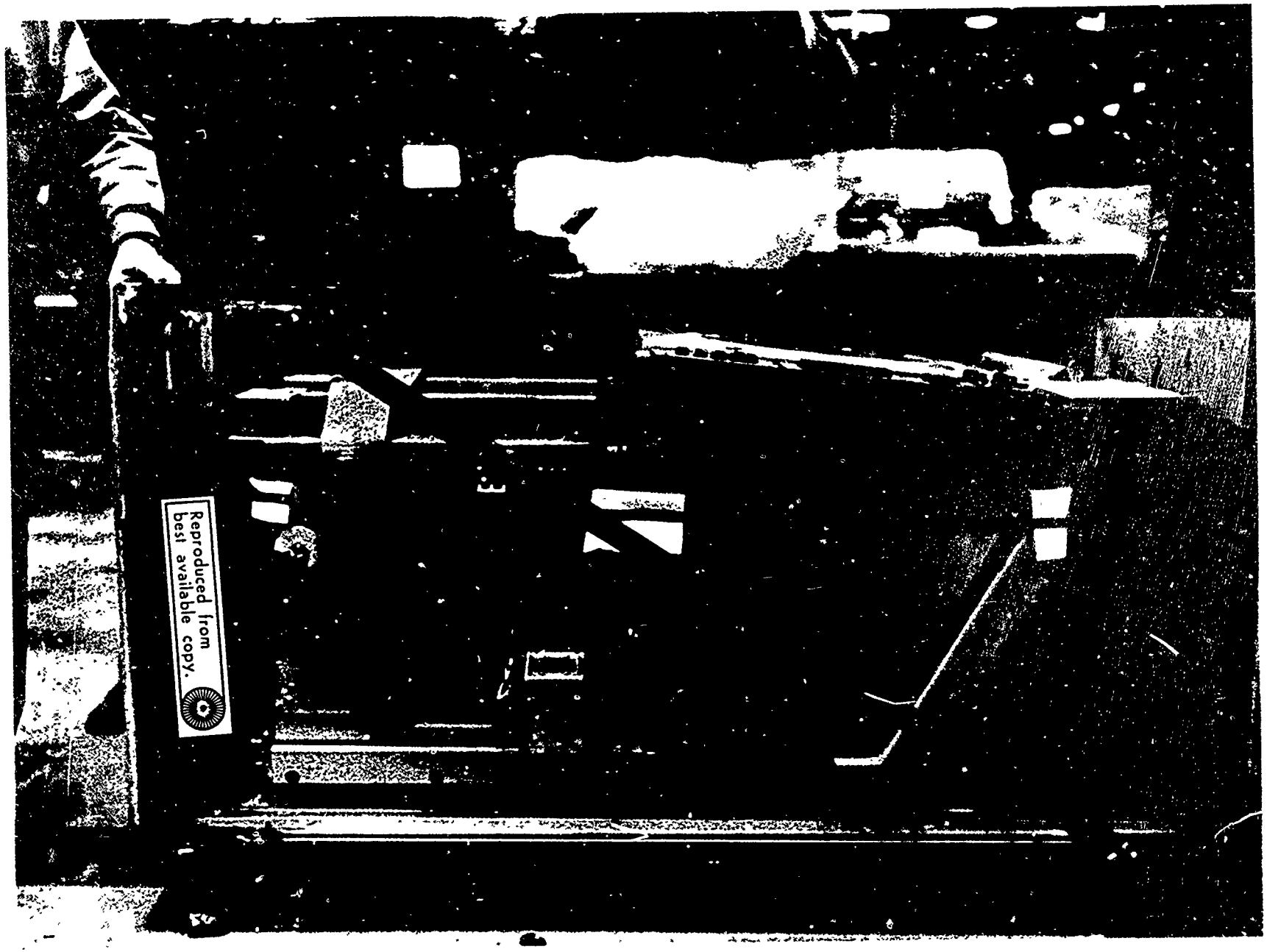

FIGURE 2 - SHIPPING CASE SHOWING PVD IN POSITION WHEN TRAVELLING

CONTROLLER BRIEFING

EVALUATION OF THE LEGIBILITY OF THE NAS MODEL 3d RADAR DISPLAY IN THE VERTICAL POSITION

The purpose of this evaluation is to determine whether air traffic controllers will have any problems in viewing the NAS radar display in the vertical position. Special attention is being given to the level of room lighting, display brightness settings, and various sources of reflections on the display.

The display you will be observing is an early production version of displays that will soon be going to most centers, including this one. The information being displayed was developed for a demonstration, and while representative of what will probably be used, it is subject to modification or change. Try not to be unduly influenced by the amount of traffic, choice of symbols, maps, weather, or other contents of the display.

INSTRUCTIONS

Seat yourself at the display as comfortably as possible, in a way you feel you would use if you were actually controlling traffic. For each condition under which you are asked to make an observation, look over the entire display and determine its quality. Look to see if there are any areas where it is difficult to see the information being displayed.

When you have had sufficient time to make a judgment, fill out the short questionnaire that has been provided. Fill out one questionnaire for each change in lighting or scope brightness. Feel free to offer any comments about the displays.

Thank you for your help.

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FIGURE 3 - CONTROLLER BRIEFING

QUESTIONNAIRE
NAS MODEL 3d LEGIBILITY

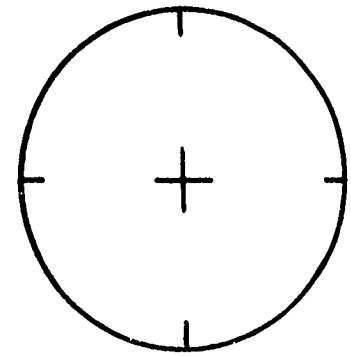
Location: ATL CLE OAK Date_____ Time_____

Brightness_____ Ambient_____

CONTROLLER_____

1. Did you have any difficulty seeing any part of the display? Yes__ No__

2. If "yes" to Question 1, outline the area in the adjacent diagram where the problem, or problems, were.



3. If "yes" to Question 1, what, in your opinion, was the cause of the problem? (check one or more of the items below)

   ( ) Reflections or glare
   ( ) Insufficient brightness of the display
   ( ) Insufficient contrast of the display
   ( ) Other (specify) _____

   _____

4. If "yes" to Question 1, how severe was the problem? Check one of the following:

   A. Could not see what was displayed_____
   B. Could barely see what was displayed_____
   C. Could see with some effort_____

5. Under these conditions, what is your overall evaluation of the quality of the display for air traffic control? (check one)

   ( ) excellent ( ) very good ( ) fair ( ) acceptable ( ) not acceptable

COMMENTS

FIGURE 4 - QUESTIONNAIRE: NAS MODEL 3d LEGIBILITY

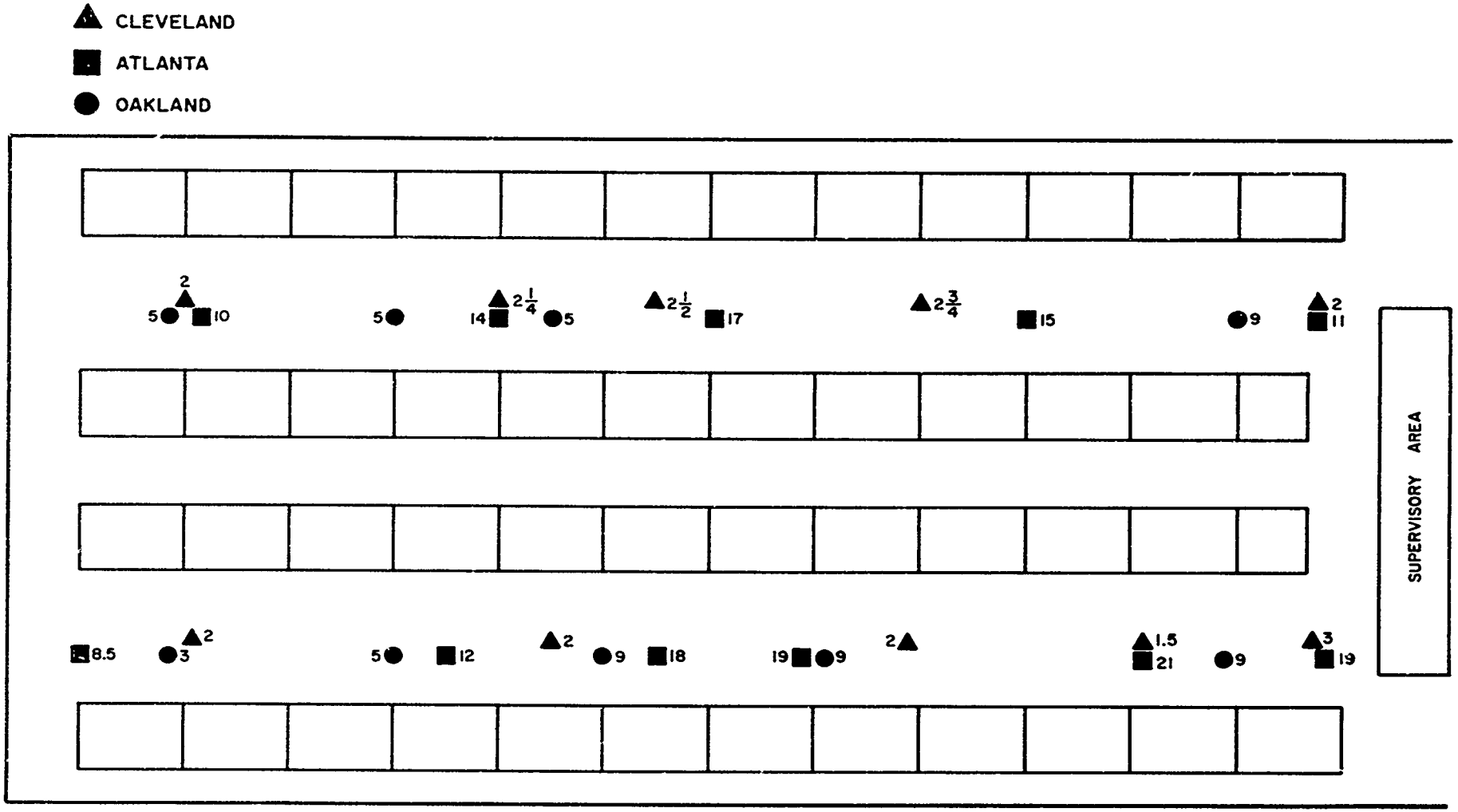


FIGURE 5 - AMBIENT LIGHT LEVELS, MEASURED IN FOOTCANDLES, IN COMPARABLE LOCATIONS AT THE THREE CENTERS.

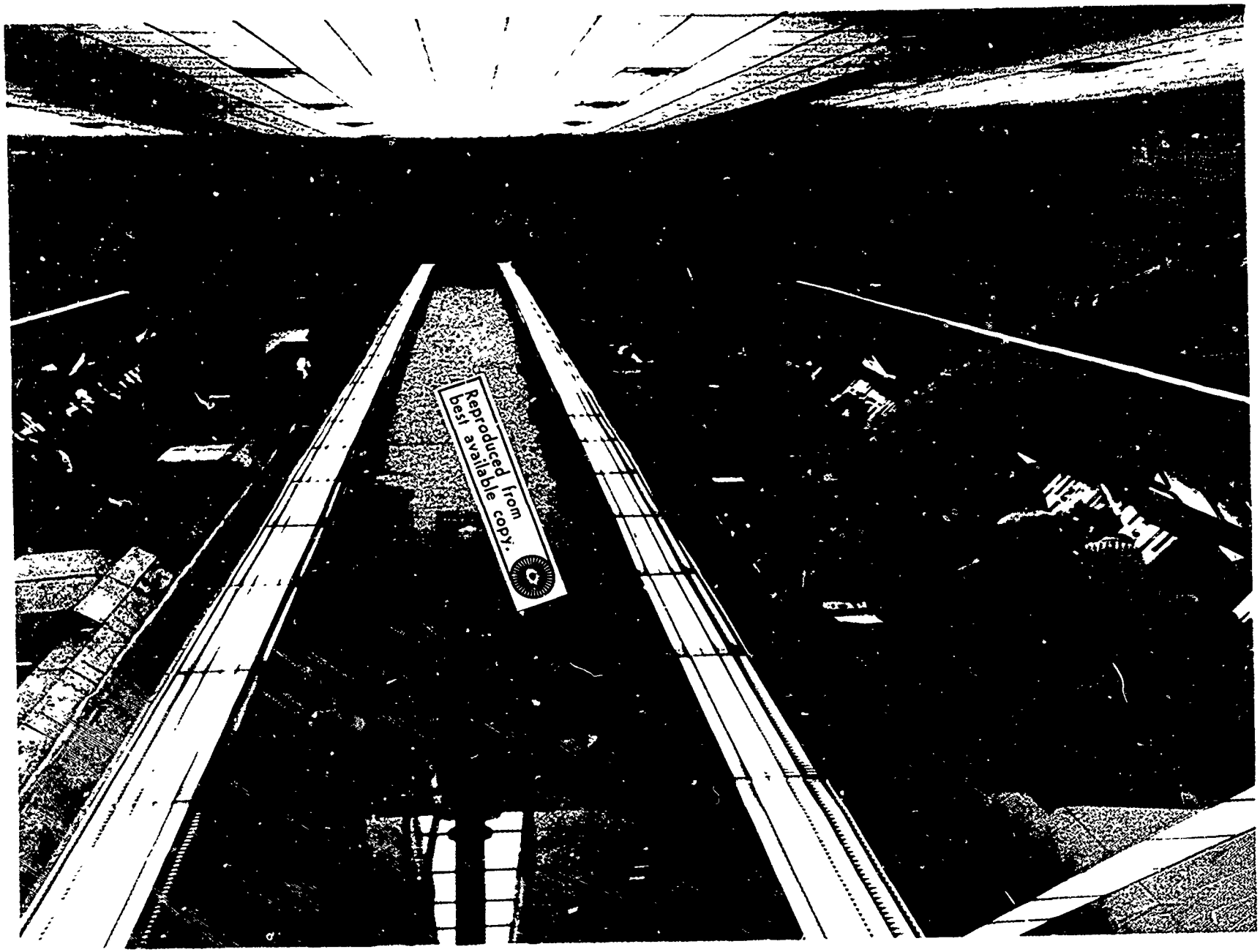


FIGURE 6 - GALLERY VIEW OF CLEVELAND CENTER SHOWING PLENUM LIGHTS ON

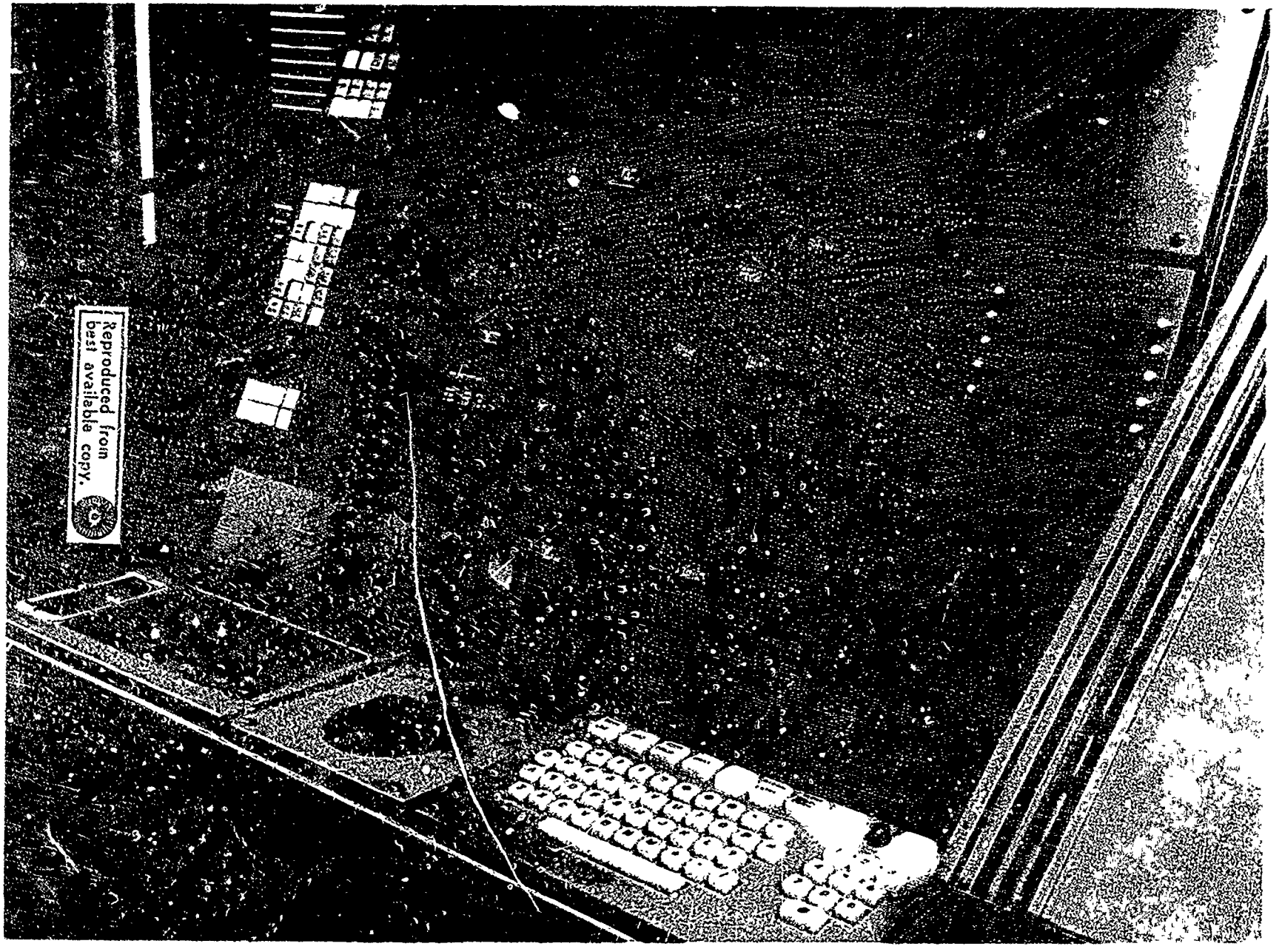


FIGURE 7 - PVD AT THE ATLANTA CENTER, SHOWING REFLECTIONS OF THE GALLERY BEHIND THE DISPLAY

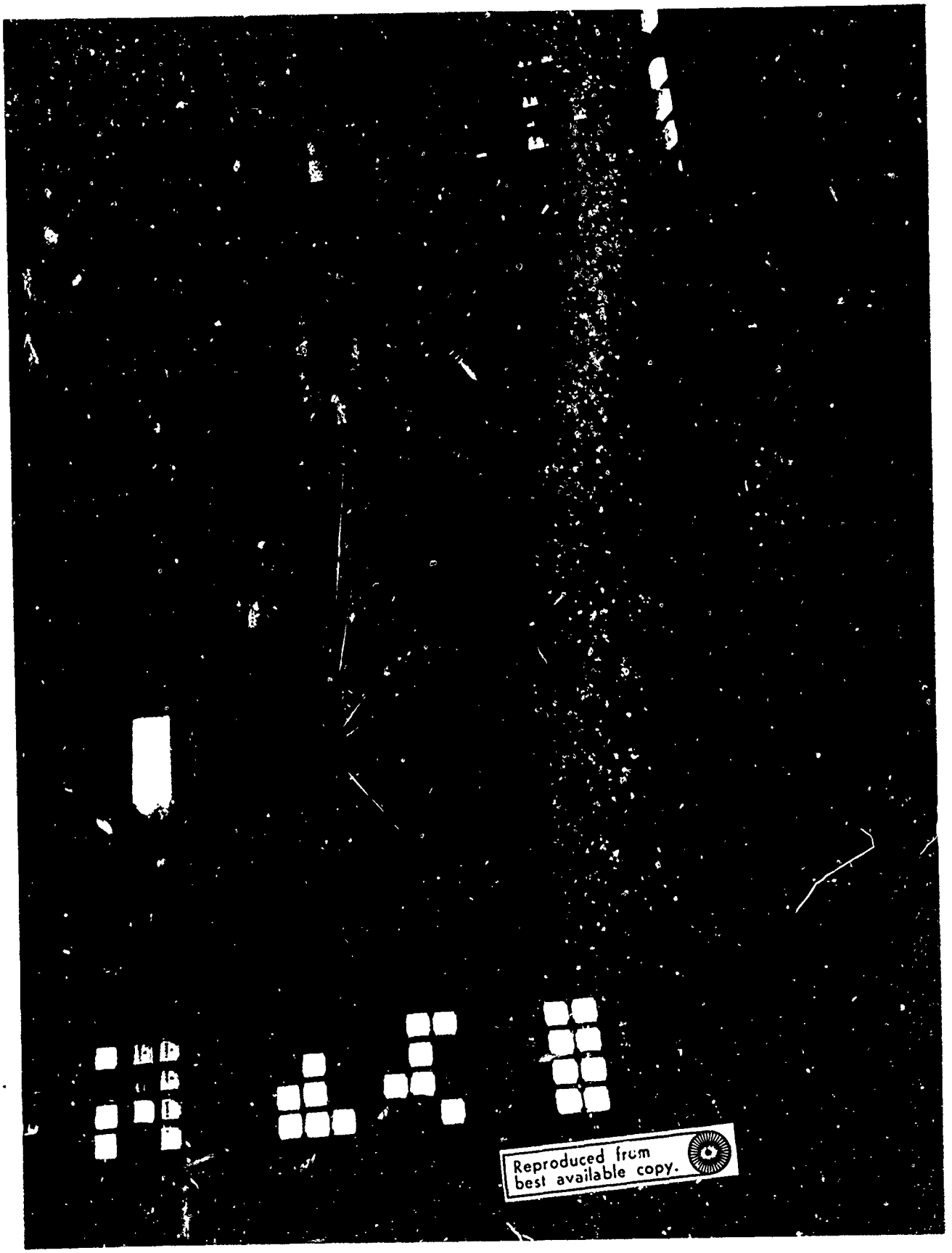


FIGURE 8 - PVD AT THE OAKLAND CENTER, SHOWING REFLECTIONS OF CEILING LIGHTS

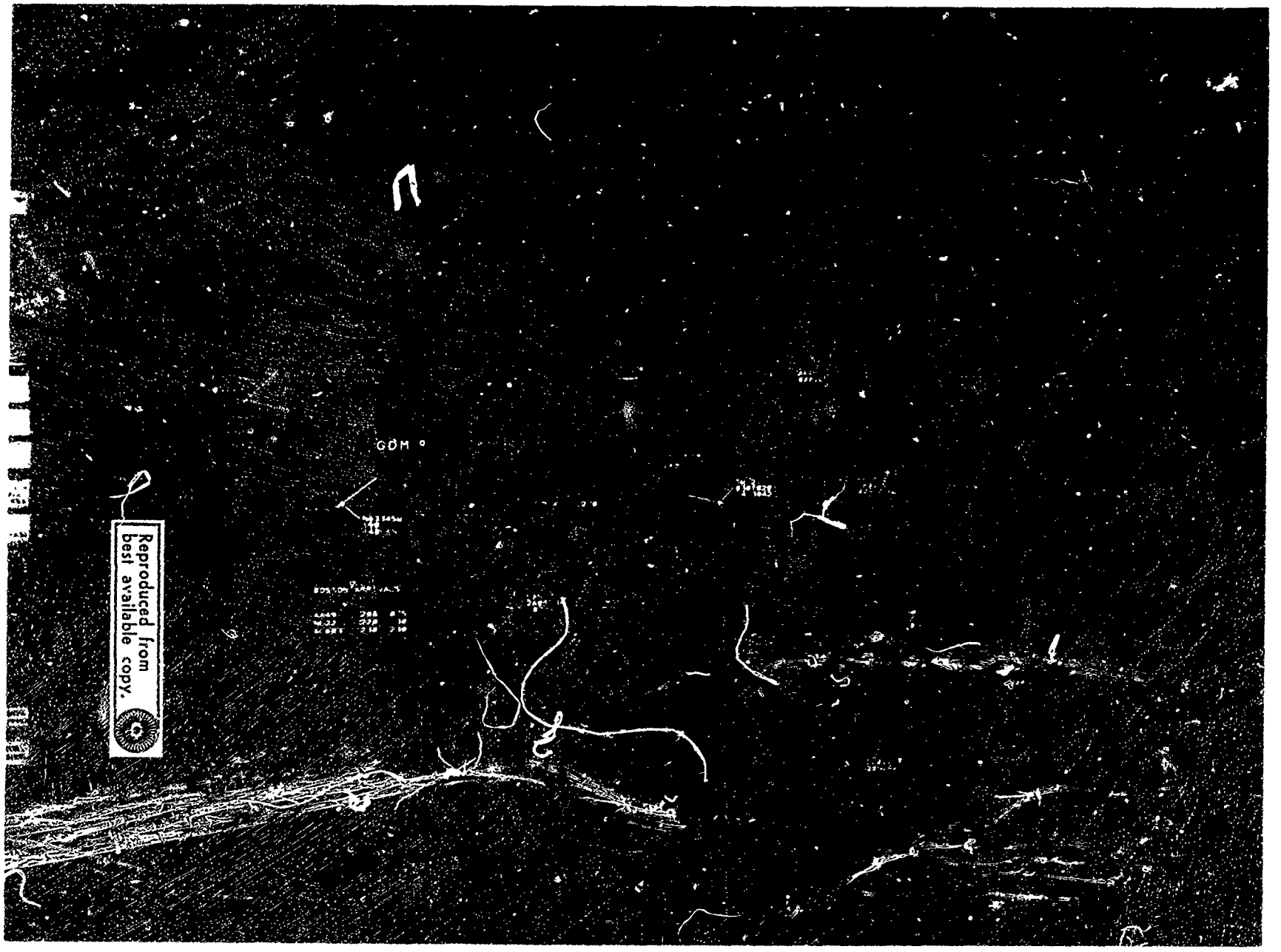


FIGURE 9 - PVD AT CLEVELAND CENTER, SHOWING REFLECTIONS OF CEILING WITH PLENUM LIGHTS ON

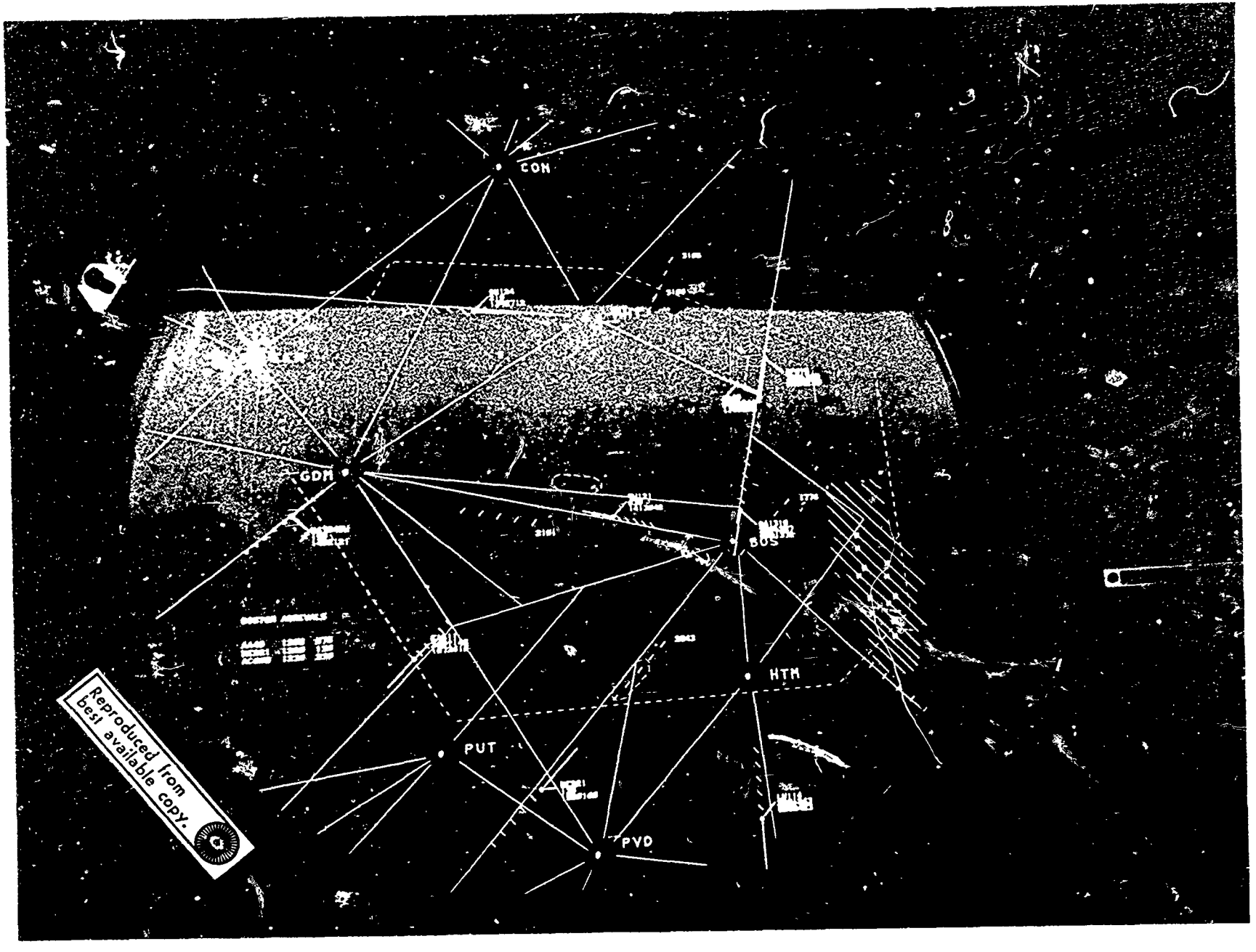


FIGURE 10 - PVD AT CLEVELAND CENTER, SAFETY SHIELD REMOVED